THE EFFECTS OF FLIPPING AN UNDERGRADUATE PRECALCULUS CLASS

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by
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Abstract

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The flipped classroom model of instruction has become an alternative to traditional, lecture-based instruction. This study examined the effects of flipping an undergraduate precalculus class in a small, private, Christian college in the southeastern United States. An experiment was conducted to compare scores on common assessments between a control group (n=21) taught with the traditional lecture-based model of instruction and an experimental group (n=21) taught with the flipped classroom model. There was not a significant difference in final exam scores for the control class (M=25.9, SD=9.3) and the experimental class (M=25.7, SD=5.4); $t(40)$=0.06, p=0.95. The flipped condition had no discernable effect on final exam scores. Both groups performed equally well. Student perceptions of the flipped classroom were solicited through a survey and revealed mixed feelings toward the new model. Some students embraced and appreciated the change in instruction, while others did not. The study concludes with the positive effects the flipped classroom had on me, my reflections, and suggestions for further research.

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To my family who stepped in when I was absent, thank you. To my wife and children who constantly encouraged me to persist, thank you. And to the one who makes my work all worthwhile, my savior, Jesus Christ, thank you.

Dedication

This dissertation is dedicated to my wife, Susan, and my children, Annmarie and Isaac. Your patience, love, and laughter have sustained me.

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The Effects of Flipping an Undergraduate Precalculus Class

Teaching college level precalculus has provided me with a first-hand experience with the persistent decline in the number of students in STEM (science, technology, engineering, or mathematics) majors, a problem that raises concern about the future of STEM related job needs in the United States (Business-Higher, 2010; Daempfle, 2003; Drew, 2011; Rask, 2010; Watkins & Mazur, 2013). The Business-Higher Education Forum (2010) touts the issue as, "…one of our nation's most critical challenges" (p. 2) while Carnevale, Smith, and Melton (2011) have reported an ongoing debate concerning an oversupply or undersupply of STEM majors. The STEM report (Carnevale et al., 2011) attempts to resolve the contradictory sides of the debate by focusing on the shift in the workforce needs of the United States as it tries to remain globally competitive in innovation that typically comes from scientists working in research and development. The report states that STEM competencies are desired in jobs that are not typically referred to as STEM related, and STEM trained graduates are being diverted to those jobs leaving an undersupply of STEM trained graduates for the STEM jobs. Whether the reasons are definitive or not, the increased focus in higher education on STEM areas by policy makers makes it clear that education is necessary to improve the quantity and quality of our nation's STEM majors.

The President's Council of Advisors on Science and Technology (2012) recently wrote a report to the President suggesting ways to improve STEM education for undergraduates. The first suggestion included adopting researched-based methods of teaching, and the council wrote that:

> Classroom approaches that engage students in "active learning" improve retention of information and critical thinking skills, compared with a sole reliance on lecturing, and increase persistence of students in STEM majors. STEM faculty need to adopt teaching methods supported by evidence derived from experimental learning research as well as from learning assessment in STEM courses. (p. 2)

It is clear from the report that lecturing as the sole method of instruction in undergraduate classes is under scrutiny. There is a call for professors to pay attention to what researchers are saying about teaching and learning, which is that the traditional lecture is insufficient for the process of learning. Over the last five years I have attempted to deviate from the lecture-only method of teaching, by slowly incorporating class activities that offer my students a chance to become more active, rather than passive learners, but I have not made sweeping changes that are suggested in the teaching and learning literature. Andrews, Leonard, Colgrove, and Kalinowski (2011) found that student learning improved in classes taught by science education researchers experimenting with active learning strategies, but gains were not found in classes taught by science professors with limited experience with education research who attempted to use the same active learning strategies. The implication is that professors with a better understanding of teaching and learning are more likely to see results from new teaching strategies.

Through a workshop, I was introduced to the "flipped learning" model that has recently become a popular teaching method. I was intrigued by the "flipped learning" model because it embraced several researched-based learning principles such as the importance of prior knowledge, the role of motivation in learning, the effect of feedback on learning, and the necessity of modelling how to apply component skills to complex tasks. Each of these principles has shown promise in improving student learning and motivation–goals that are sought for improving STEM education.

The “flipped classroom” is a somewhat simple idea that flips the traditional model of teaching. Instead of a teacher disseminating knowledge through a lecture and expecting students to apply the knowledge through outside-of-class assignments, the flipped model has students learning important material outside of class, typically via video-recorded or audio-recorded lectures, or by reading a text, and the application of knowledge is moved to in-class assignments and projects (Hamdan, McKnight, McKnight, & Arfstrom, 2013). The idea of the flipped class is not necessarily new, but has become a popular teaching strategy through the work of Bergmann and Sams (2012). Bergmann and Sams have promoted the “flipped learning” pedagogy through the creation of The Flipped Learning Network website, and by writing the book, *Flip Your Classroom: Reach Every Student in Every Class Every Day* (2012). Their ideas were cultivated from experiences they had recording lectures with video and audio to help students who missed classes or needed to have information from lectures repeated in their high school chemistry classes. Their “flipped classroom” idea developed into an appealing teaching method due to available technologies to disseminate class material and growing political pressures to improve student learning.

Bergmann and Sams (2012) wrote that there is no such thing as *the* flipped classroom. There are many versions, all exhibiting a similar idea that provides a teacher more time to interact and get to know his or her students. The structure of a flipped classroom provides students more time to work collaboratively with peers and provides students more time to actively use what they have learned in context-specific applications. These provisions of time are created by not lecturing students on knowledge that can be learned elsewhere. In the flipped classroom students learn basic content and vocabulary outside of class. The content delivery outside of class can take on many forms such as watching teacher-made video lectures, watching videos from online repositories, or simply reading a textbook.

Moving away from the traditional whole class lecture stems from a push in education to personalize or differentiate instruction for each student, because not all students have the same learning styles (Wormeli, 2007). Differentiation is difficult with the traditional lecture-only method; in the flipped classroom students who need more time to process information from a videoed lecture can stop, rewind, and repeat parts of it or can read text selections multiple times. Students who get bored with in-class lectures because they do not need the introductory pace can quickly scan materials outside of class. Using the time normally spent for whole class lectures, teachers can design in-class activities that differentiate and personalize instruction for more students.

A flipped classroom is not necessarily a new method of teaching. Rather, it is an older idea that has become more organized and has attracted more attention as educators search for more effective ways to teach. Lage, Platt, and Treglia (2000) used the phrase “inverted classroom” in their study of the perceptions of students and instructors in introductory economics courses. The inverted classroom method is an earlier version of the flipped classroom. Their study found evidence of positive perceptions of the inverted classroom structure by students and faculty, but the effect on student learning was not addressed. Strayer (2012) also used the phrase inverted classroom in his study of differences between classroom environments. He found positive influences on student cooperation with peers, and openness to innovative teaching methods, but noted that students were unsettled by the structure of the course since it was a drastic change from the traditional classroom structure.

While his study is important to help educators understand student perceptions of the inverted classroom, it did not address the issue of whether the inverted classroom had an impact on student learning. Goodwin and Miller (2013) have commented that evidence on flipped classrooms is being reported on social media websites, but not at a sufficient level to be called research-based.

For flipped learning to become an accepted instructional practice, more scientific research should be conducted on its effects, positive or negative. While debates are ongoing about what methodologies should be labeled as research-based (Eisenhart & Towne, 2003; Feuer, Towne, & Shavelson, 2002), the experiment is still a respectable method that adds to the knowledge base, especially for a topic with so much exposure, but relatively scant evidence of effectiveness. McGowan has written, “It is commonly known that a well-designed randomized experiment is the best method for establishing efficacy of any intervention, be it medical, behavioral, or educational in nature” (2011, p.1), and Cook and Sinha (2006) have written that, “…the strongest research will combine experimental and qualitative methods” (p. 562). Flipped designs are cropping up in many K-12 classrooms and college classrooms in the hope that student learning will improve, but there is a need to know if the flipped learning method does, in fact, bolster student learning.

While I am interested in my students attaining the skills and knowledge they need to be successful in STEM majors, or be better prepared for jobs outside of STEM fields that require STEM related knowledge, I am also interested in how best to help them gain that knowledge through my teaching practices. With an understanding of theories about teaching and learning discussed in the literature review, I flipped my precalculus class. Thus, the purpose of this study was to test the effectiveness of flipping a precalculus college class in a small, private college in the southeastern United States. Did changing from a primarily lecture-based method to a flipped classroom increase students' learning, and what effect did it have on the students' opinion of the flipped classroom model?

Literature Review

Flipped classrooms are not new phenomena, but with technological advances and increased focus on improving teaching and learning they are becoming widely popular. The Flipped Learning Network, a website devoted to helping educators flip their classrooms, has over 13,000 members sharing personal experiences about flipping their classes, and many participants boast of improved student learning. While these posts do not offer verifiable evidence of the effects of flipped classrooms, the sheer quantity of posts indicate that flipped learning is a method worthy of more scrutiny.

Flipped Learning Defined

Flipped learning is an instruction design that replaces the traditional lecture-in-class/assign practice for homework model with assigned learning activities for homework/practice problems in class model, hence the term flipped classroom (Hamden, McKnight, McKnight, & Arfstrom, 2013). Other terms have been used for this design, such as interactive teaching (Walvoord & Anderson, 1998) and inverted teaching (Lage et al., 2000; Strayer, 2012). Blended, hybrid, and e-learning are other terms circulating in the literature that share some similarities with flipped classrooms, but refer to the mixing of face-to-face class time with online learning (Snart, 2010). In blended or hybrid classes there is a trade-off of class time with online learning components such as discussion boards. In flipped classrooms there is no trade-off; class time is still preserved as a whole group meeting albeit students may work in cooperative groups within the whole group session. The main point is that whole group sessions in a flipped classroom are not lectures given by an instructor, but rather student-centered activities led by an instructor.

Four Key Elements of Flipped Classrooms

Although there is no prescribed method for flipping a classroom because of the abundance of instructional strategies that can occur inside and outside of the classroom, there are, according to Brame (2013), four common key elements indicative of the flipped classroom:

- an opportunity for students to gain first exposure prior to class (¶ 8)
- an incentive for students to prepare for class (¶ 9)
- a mechanism to assess student understanding (¶ 10)
- in-class activities that focus on higher level cognitive activities (¶ 11)

These elements are the backbone of a flipped classroom, and each one is tied to important research-based learning principles that make the flipped classroom a potential teaching method that can improve student learning. Ambrose, Bridges, DiPietro, Lovett, and Norman (2010) have compiled a list of seven researched-based principles to guide teachers in understanding why teaching approaches do, or do not, support student learning. Four of these principles have direct ties with the four elements of a flipped classroom. In the following paragraphs each element is described, and a connection is made between the element and the research-based learning principle discussed from the work of Ambrose et al. (2010). Examples of teaching strategies that are germane to this study are included.

Element 1: An opportunity for students to gain first exposure prior to class. Instead of students being introduced to content through a whole class lecture, the instructor in a flipped classroom, “[provides] an opportunity for students to gain first exposure prior to class” (Brame, 2013, ¶ 8). Logistically, moving initial exposure of content outside of class frees up class time for activities that involve higher levels of learning, but strategically it provides an instructor the opportunity to help students retrieve and build upon prior knowledge. In a traditional model of instruction students’ prior knowledge is typically prompted through some type of warm-up activity, a review of homework problems, or simply part of a lecture devoted to reminding students of previously learned material. It takes valuable class time to do these types of activities in class, but the flipped model requires that some if not all the prompting of prior knowledge takes place outside of class.

Ambrose et al. (2010) suggest in their first learning principle that, “Students’ prior knowledge can help or hinder learning” (p. 13). Students learn by making connections to what they already know, and interpret new knowledge through a lens created by prior knowledge (National Research Council, 2000; Vygotsky, 1978). Having students look at content material via reading a text or watching a video outside of the confines of time and space in a classroom will provide students time to think about what they already know, and help them begin the process of assimilating content that may be foreign to them. If students have inaccurate knowledge it can hinder learning as well, so it is important that an instructor assess what students know before designing learning activities.

In the field of mathematics it is crucial for students to make connections with prior content. Complex mathematical content is best learned in stages, building upon and adding to foundational content. Sloyer (2004) relates an example of how students could successfully develop the formula for computing the volume of a cup, but only after prompting students to remember prior knowledge about the volumes of typical three-dimensional figures and the technique of breaking complex objects down into component parts, both of which students had studied in previous classes.

Having students learn and practice some basic concepts before coming to class helps students create knowledge or retrieve prior knowledge so they are prepared to learn at a deeper level. The works of Sweller, van Merrienboer, and Paas (1998) and Paas, Renkl, and Sweller (2004) use Cognitive Load Theory to explain that learning is a process of creating chunks of stored knowledge called schema. Since humans have a limited working memory that can only process a few things at one time, we have to rely on long-term memory to store what we know. As schemas are developed and connected together they are stored and retrieved from long-term memory when needed. Related, simple schemas combine to form more complex schemas. As schemas become more complex, the connections become more automated within the schema, freeing up the working memory for more processing. This freeing up of the working memory is described as decreasing the cognitive load. When students are bombarded with lots of new information with limited connections, their cognitive load is high because their minds are busy creating schemas and connecting them to other schemas. Paas et al. (2004) say that if a student's cognitive load is either too low or too high his or her learning is degraded. Too little challenge will make students become bored, while too much of challenge can cause students to shut down or withdraw. For this reason instructional designs need to be tailored in such a way as to challenge students without overloading them cognitively.

"Peer instruction" is an example from the literature that explores the impact of prior knowledge on student learning and comes from a line of research developed by Crouch and Mazur (2001). In their "Peer Instruction" method used in undergraduate introductory physics classes for non-majors, students are asked to read material before class. During class the professor assigns a ConcepTest, a question concerning a concept being studied, that students answer individually and submit to the professor. The professor then asks students to discuss their answers in peer groups. The professor listens to student discussions to identify misconceptions and asks students to resubmit answers. The professor either moves on to the next topic or delivers a mini lecture addressing misconceptions if needed. Crouch and Mazur (2001) used this approach with classes containing over 100 students, collected data over 10 years, and reported significant gains in learning based on standardized tests and conceptual understanding inventories. Their teaching model exemplifies the prior knowledge learning principle and decreases the cognitive load for students by having them read content before coming to class.

The flipped classroom model offers a way for instructors to help students create and strengthen schema outside of class, thus reducing the cognitive load required for deeper learning inside the class. If students are directed toward opportunities to think about prior knowledge outside of class, the cognitive load will decrease and learning will be more manageable while students are in class.

For students to be successful in a flipped learning environment, they will need access to resources outside of class. Wireless internet access has made it possible for students to have access to materials, such as video repositories and online homework delivery systems, that are designed to coincide with textbooks. WebAssign is an example of an online homework delivery system that includes features beneficial to the flipped classroom, such as video explanations of topics that are embedded within the pages of an electronic textbook; multiple choice, multiple selection, and short answer questions written by the textbook authors that students can interact with to get instant feedback; practice quizzes that can be taken multiple times with randomly generated questions; and videos of example problems. Allain and Williams (2006) reported that students using WebAssign outside of class to submit homework did not show improvement in conceptual understanding or test scores; however, students reported they spent more time studying course materials outside of class if the homework was graded. The class was taught in a traditional manner, and students only accessed WebAssign outside of class. In a flipped classroom WebAssign could be used as an in-class tool for students to work cooperatively and have the benefit of instructor help when needed. Instructors could use WebAssign outside of class to provide students the resources to gain first exposure to class material, take low stakes practice quizzes to identify misunderstandings, and develop questions to be asked in class.

Furthermore, students need to organize their prior knowledge and make connections between prior knowledge and new material. The Cornelle Note-taking method exemplified in Donohoo (2010) is a tool professors can use to help students organize their thoughts and make connections. The method has students divide a page into three sections: a cue section for key words or questions, a main idea section for notes and examples, and a small summary section at the bottom of the page. Undergraduate students who have not learned the art of note-taking will gain the skills to organize the material they are exposed to outside of class and identify gaps in their learning.

The videos and resources embedded in WebAssign and the Cornelle Note-taking strategy are learning tools professors can use in a flipped classroom to provide students with an opportunity to gain first exposure of material outside of class as suggested in element 1. The challenge is to get students to do the outside-of-class work, which leads to element 2 of the flipped model.

Element 2: Provide an incentive for students to prepare for class. Brame (2013, ¶ 9) noted that students must be motivated to carry out the work required to prepare for class. Motivation is important, and necessary, especially when it comes to learning. Ambrose et al. (2010) state in their third learning principle, "Students' motivation determines, directs, and sustains what they do to learn" (p. 69). Many theories are posited about motivation, and most have at their core two main concepts: motivation to achieve a goal depends on the subjective value of the goal and the expectancies that surround the successful attainment of the goal (Bandura, 1986; Wigfield & Eccles, 1992, 2000). Students will set goals or purposeful actions based on the values they place on the goals and the expectancies they have regarding the goals.

It is important to understand that there are different types of goals that students set for themselves. Performance goals are those that are concerned with judgments about competence, such as the goal of getting a good grade, while learning goals are those that are concerned with increasing competence, such as truly wanting to know how to solve quadratic equations (Dweck & Leggett, 1988) . Affective goals, such as wanting to engage in a stimulating activity and social goals are other types of goals that are motivating, but not often topics in higher education (Ford, 1992). Students come to classes with these different types of learning goals, and a one-size-fits-all approach simply does not motivate all students equally. Designing instruction to focus on one type of goal that the majority of students set could still be futile because as some research shows students can have multiple types of goals simultaneously (Valle et al., 2003). Actually, the research shows that students with multiple types of goals are more successful than those with only one type of goal.

The motivation to work at achieving a goal comes from the value placed on the goal. Wigfield and Eccles (1992, 2000) separate the sources of value into three categories: attainment value (the satisfaction of completing a task), intrinsic value (the satisfaction of performing the actions of the task), and instrumental value (the satisfaction of achieving a short-term goal in order to work toward a longer-term goal). These values can work alone or in concert with one another. The value a student places on a goal can also change as knowledge is gained. Hidi and Renninger (2006) developed a model of how interest develops in four phases: triggered situational interest, maintained situational interest, emerging individual interest, and well-developed individual interest. This research suggests that interest builds from first exposure and grows if value is placed on what is being learned. Advocates for the flipped classroom model believe the prior learning activities that take place outside of the class will contribute to triggered situational interest, and it is important to design in-class activities that will help students attach value to the activities, in turn moving them further along the interest continuum toward well-developed individual interest.

Another component of motivation is expectancy. Bandura (1977, 1993, 2012) says that there are two forms of expectancies: outcome expectancies and efficacy expectancies. Outcome expectancy is the expectation that a specific action will bring about a desired outcome. For example, a student can believe that taking notes typically helps to get better grades. Thus, if a student holds this belief about note-taking he is more motivated to take notes. Efficacy expectations are different and are described as being beliefs that a person has about whether one is able to carry out a course of action in order to bring about a desired outcome. Extending the example on note-taking, just because a student believes note taking is helpful (outcome expectancy) does not mean the student holds the belief that he can take notes in such a way as to help him perform better on a test (efficacy expectation). The student may harbor doubts about his capabilities with note-taking that may affect how motivated he is to take notes.

From the research on motivation it is clear that any teaching model needs to include strategies to increase student motivation by helping students place value on the content of the class, place value on the activities designed to nurture learning, develop expectancies that the activities they are participating in will lead to goal achievement, and develop expectancies that goal achievement is within their personal grasp to attain. The flipped classroom model provides the instructor the opportunities to develop varying activities that can address a range of goals students bring to the classroom and to motivate students in different ways that typical lecture-only models cannot. Once students are properly motivated, and motivation is sustained, the focus moves to ensuring students are learning what they are expected to learn which leads to the third element of the flipped classroom.

Element 3: *Provide a mechanism to assess student understanding*. Brame (2013, ¶ 10) described this mechanism as the third component to the flipped classroom model. Research in higher education is exploring how assessment aids in student learning. While grades from summative assessments are powerful motivators for students, research is showing that formative assessments are more beneficial in helping students learn (Black & Wiliam, 2010; Lipnevich & Smith, 2009). Lipnevich and Smith (2009) describe formative assessment as a means to identify discrepancies between what a student knows and what the student needs to know based on course goals and objectives. Grades can give students an indication of the magnitude of the discrepancy, but carefully crafted feedback is what students need to help them close the gaps that exist in their knowledge. Thus, the fifth learning principle offered by Ambrose et al. (2010), "Goal-directed practice coupled with targeted feedback enhances the quality of students' learning" is the guiding mechanism for element 3.

The purpose of feedback is to contribute to student learning. Yorke (2003) explains:

> There is [*sic*] a range of ways in which assessors can provide feedback on student performances – comments can be written on assignments, be given orally following an assessed presentation of some sort, or be given quickly during a learning activity which is not formally assessed. (p. 481)

Formative assessment can be feedback on a variety of activities. The timing of feedback is crucial to making an assessment formative. Formative assessment is beneficial to learning because feedback is given at a time when students have an opportunity to adjust learning behavior, whereas summative assessment only offers a judgment of learning after the fact. In a flipped classroom model, the time available for professors to give feedback is greatly increased. If students are developing and thinking about prior knowledge outside of class, then the professor has time to assign alternative assessments in-class where feedback from classmates or the professor can be immediately given. Students can use the feedback to adjust their efforts if needed.

According to Hattie and Temperley (2007), feedback should address three main questions: What were the goals being assessed, where is the student's understanding in relation to the goal, and what does the student need to do to reach the goal if it is not met? Hattie and Temperley (2007) describe feedback as a consequence of performance, so feedback does not always come directly from a professor; it can come in the form of a computer showing a green check or a red “X,” peers sharing their knowledge, the answer in the back of a textbook, or even a self-evaluation of one’s work. Feedback can come in many forms, so professors have multiple options that may not be possible when using a traditional lecture-only classroom model. The flipped classroom model will allow time for professors to provide different forms of feedback.

Winne and Butler (1994) summarize that “feedback is information with which a learner can confirm, add to, overwrite, tune, or restructure information in memory, whether that information is domain knowledge, meta-cognitive knowledge, beliefs about self and tasks, or cognitive tactics and strategies” (p. 5740). Therefore, feedback speaks to more than just correctness of a problem on an assignment. For example, a red x on a student’s work in mathematics is helpful in the learning process, but a comment guiding a student to find his error is more informative. Feedback can have effects on many aspects of learning, and it can be harnessed to provide students with life-long learning strategies. Hattie and Temperley (2007) categorize feedback into four types: feedback about the task (correct/incorrect), feedback about the processing of the task (getting students to think about how they get answers), feedback about self-regulation (getting students to internally monitor their learning), and feedback about the self as a person (feedback that affects self-esteem and self-efficacy). In their meta-analysis of studies, Hattie and Temperley (2007) found that the first three types of feedback were most beneficial to learning, whereas feedback about the self as a person was the least helpful for learning.

The flipped classroom model requires setting appropriate goals and providing appropriate feedback to see increased student learning. Students that are not accustomed to types of feedback that are not simply a statement of right or wrong will need help with responses to better forms of feedback. Black and Wiliam (2010) state:

> Some pupils will resist attempts to change accustomed routines, for any such change is uncomfortable, and emphasis on the challenge to think for yourself (and not just to work harder) can be threatening to many. Pupils cannot be expected to believe in the value of changes for their learning before they have experienced the benefits of such changes. Moreover, many of the initiatives that are needed take more class time, particularly when a central purpose is to change the outlook on learning and the working methods of pupils. (p. 87)

Because the flipped classroom model will be a change for most students, it is imperative that feedback be given to help students learn content and to help them develop skills to become self-directed learners. Feedback is important for students' outside-of-class work to ensure proper foundational knowledge, and it is also important for what students will do in class.

Element 4: Provide in-class activities that focus on higher level cognitive activities. Brame (2013, ¶ 11) completes the flipped classroom model with the fourth element. The benefit of shifting initial exposure of content outside of class is additional in-class time to allow students to work on activities that are at a higher cognitive level. While cognitive levels have been organized in multiple ways, one of the most common is Bloom's Taxonomy (Krathwohl, 2002). The original Bloom Taxonomy contains a hierarchical list of terms used to categorize the cognitive domain ranging from concrete to abstract. The six levels listed from simplest to most complex are knowledge, comprehension, application, analysis, synthesis, and evaluation. These nouns were used to categorize the cognitive demands of learning objectives and goals, and each level was broken down into subcategories. Scholars believed that in order to accomplish a certain level, the levels below had to be mastered. Krathwohl (2002) describes that the taxonomy was revised as a result of research on learning and cognition, and verbs were used to list the levels as remember, understand, apply, analyze, evaluate, and create. The new taxonomy does not change the original idea; it incorporates the new information about how knowledge is viewed and acquired. The main goals of education are to facilitate student's mastery of a domain by providing learning tasks at each of the levels in Blooms Taxonomy and help students transfer what they learn beyond the classroom.

The fourth learning principle posited by Ambrose et al. (2010), "To develop mastery, students must acquire component skills, practice integrating them, and know when to apply what they have learned" (p. 95) is the guiding principle for element 4 of the flipped classroom model. Ambrose et al. (2010) describe the professor as an expert who has knowledge of a domain and organizes, accesses, and applies the knowledge in different ways than a novice would (Koedinger & Anderson, 1990). Professors use domain knowledge unconsciously because of the familiarity and automation of skills, whereas students need more time and practice when learning. Kim (2012) points out in her work:

> If we wish to create an instructional program aimed at developing expertise in particular domains, we need to understand students' levels of understanding, monitor their progress, and provide personalized feedback. Students in different stages may have different needs because of the diverse states in their mental representations. In other words, instruction needs to be adaptive to individual differences. (p. 617)

Professors have to be cognizant of the differences among students and design instruction to help students master a domain.

In the context of mathematics, component skills are necessary for higher-level cognitive activities such as developing mathematical models to describe real-world phenomena. When an expert finds that a linear relationship exists between two quantities, the process of writing a function to model the relationship is automatic, and there is vocabulary the expert uses to describe the relationship depending on the context surrounding the quantities. The idea of linear function spans many fields, and each field associates its own vocabulary with the concept of linear functions. Students in a precalculus class can learn the process of writing a linear function given two points by following a prescribed process, considered a component skill, but they also need to learn when it is appropriate to use a linear function as a model. As Gordon, Narayan, Baxter Hastings, and Gordon (2006) state:

> We, and faculty in other disciplines, expect students to understand the significance of the base (growth or decay factor) in an exponential function. We expect them to comprehend what the parameters in a sinusoidal function tell about the phenomenon being modeled. We expect them to understand the significance of the derivative of a function and the significance of a definite integral. But, if students cannot create the connection between the slope of a line and its meaning in a context, it is clear that we should not expect them to create comparable connections of more sophisticated ideas on their own. It is our job to help them make those connections by emphasizing the meaning of the concepts, not just emphasizing the formulas to be memorized and applied by rote. (p. 71)

This type of learning comes from a focused effort to provide practice for students to make connections between component skills and applications. Practicing component skills is important, but knowing when and why to apply component skills should be important goals for students as well. Therefore, the in-class portion of the flipped classroom model provides students time to practice the integration of component skills within problem solving tasks with the support of a professor. In traditional models of teaching this practice is usually left for students to do alone as homework.

In short, Brame (2013) suggested these four elements to flip the traditional, lecture-only college classroom. The collection of researched-based teaching and learning principles described in the work of Ambrose et al. (2010) undergirds the four elements making the flipped classroom an instructional model that should increase student learning.

In an extensive survey of research on the flipped classroom, which they explicitly defined as, “an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom,” Bishop and Verleger (2013, p. 5) found only one empirical study, Day and Foley (2006), that examined student performance throughout a semester. Bishop and Verleger (2013) recommended that future research should objectively investigate student learning outcomes with controlled experimental designs and carefully consider the theoretical framework used in flipped classroom designs.

Some current studies in specific academic disciplines and levels offer evidence that the flipped classroom model is beneficial in undergraduate education and worthy of future research. Love, Hodge, Grandgenett, and Swift (2013) reported that sophomores in an experimental flipped applied linear algebra course did as well as students in a traditional lecture-based course on common final exams, but students from the flipped class enjoyed class more than those in the lecture-based course. Although student scores were not higher, the researchers gave commendation to the flipped classroom method because it left students with more of a positive attitude toward mathematics, an admirable consequence in light of the goal to increase interest in STEM areas in undergraduate education. Gaughan (2014) flipped a first-year history course at the University of Colorado-Pueblo and reported positive effects on students engaging more with the class, but there was no data concerning students' learning outcomes. Jaster (2013a) did an extensive single-group study with two college algebra classes at the university level and looked at student perceptions with an inverted (flipped classroom) model. He found that students preferred a lecture-based model, but students also liked the problem solving done in class. Jaster's (2013b) work was detailed with how he implemented the flipped classroom model, but did not provide empirical evidence of how the flipped model of instruction compares with lecture-based instruction.

While the research of instructional models that share elements with the flipped classroom model seems transferrable to other disciplines, and levels, there exists a gap in the literature providing evidence that the flipped classroom model will increase student learning in undergraduate, introductory math courses such as precalculus. Teachers and professors are trying out the flipped classroom even though there are only a handful of studies available showing results of flipped classrooms on student learning (Crouch & Mazur, 2001; Davies, Dean, & Ball, 2013; Deslauriers, Schelew, & Wieman, 2011; Lage et al., 2000). Although the flipped classroom as a whole has not been studied thoroughly, the key elements of the flipped classroom model reflect research-based learning theory. Therefore, the flipped classroom model is worthy of research.

Methodology

Although the flipped classroom teaching model contains elements that have been shown to improve student learning, the absence of empirical evidence leaves the flipped classroom in a questionable state as a beneficial instructional model, especially for higher education. As Ross, Morrison, and Lowther (2005) point out, "…higher education has historically served much more as a context for conducting experiments than as a primary research focus" (p. 40). Higher education classrooms operate in a more autonomous fashion than compulsory educational institutions; thus teaching models in higher education settings are not often under the same scrutiny. With changes in the political climate of the United States and the globalization of our world, higher education has recently become a focus on the national stage. The extra focus has prompted professors to examine teaching models and to be as bold as to change time honored teaching practices. This study is specifically designed to test the flipped classroom model at the undergraduate level in an introductory mathematics class.

The plethora of anecdotal evidence concerning the flipped classroom model is intriguing, and has prompted lots of chatter among educators posting on educational websites. Questions remain though about the effectiveness of the flipped classroom model, especially in higher education. Thus, answering the questions as to what effect the flipped classroom model has on students' scores, and what opinions students develop about the flipped classroom model are the objectives of this study. The primary question as to whether the flipped classroom model affects students' scores is explored with an experiment, while the secondary question concerning students' opinions of the flipped classroom model is addressed through an analysis of field notes and survey responses.

This chapter describes the plan for conducting the research. It describes the setting, population, and sample for the study. The manner in which the precalculus course has been taught traditionally is described as is the prescribed instructional intervention. The instruments used in the study are described along with their reliability and validity followed by a description of how both quantitative and qualitative data were collected.

Population and Sample

This experiment took place in a private, four-year Christian university, offering both undergraduate and graduate education strongly grounded in the liberal arts while offering opportunities to prepare for various professions. According to the university's website the college serves approximately 5,000 students. The population is 63% female and 37% male, and includes representation from 37 states and 21 foreign countries. The faculty to student ratio is 1:13 with the average class size being 25. A total of 5 professional schools, 2 academic schools, and 11 academic departments offer nearly 60 undergraduate and graduate major fields of study. Students that take precalculus is the population of interest, and the students taking precalculus in the fall of 2012 and fall of 2013 constitute the sample used in this study.

Research Design

Randomization is a crucial component of experimental designs and the selection of students to be included in a control and treatment group must be done in a manner in which no bias exists in the selection process; randomization of individuals is the best procedure to ensure equivalence of comparison groups (McGowan, 2011). In this study students who registered to take precalculus were the individuals of interest. The control group was composed of 22 students taking and completing precalculus in a class that was taught using a traditional lecture-based model while the treatment group consisted of 22 students taking and completing a class that was taught using a flipped classroom model. Since the demand for a precalculus class has not exceeded the limit of 36 students in more than six years, only one section (class) is offered each semester, thus making it impossible to teach both classes in the same semester. In the fall 2012 semester, the precalculus class was taught using a traditional lecture-based model. The students had no knowledge that an experimental class would be taught in the fall of 2013 at the institution. Knowledge of a class being taught with experimental methods could have had the potential to influence whether a student decided to register for the class. My decision to experiment with a flipped classroom model was not made known to any person at the institution before students registered for the fall 2013 semester. Students or advisors of students had no knowledge that the fall 2013 precalculus class was going to be taught using the flipped classroom model. There were no programmatic changes made during the 2012 and 2013 academic years concerning mathematics requirements that would affect students' decisions to take precalculus. Therefore, since there were no significant changes to the influences on students' decisions to take the precalculus class either in fall of 2012 or the fall of 2013, each of those classes had an equally likely chance of being populated, and I contend that the classes were the result of a random process, meaning that there was no bias in the selection of individuals for the study.

An analysis was made of the constituency of the control and treatment groups by comparing aggregate student data, which in addition to demographics, includes average math SAT scores, and percentages of freshmen, sophomores, juniors and seniors. The findings of the analysis are reported in the next chapter. Since I was the investigator and the experimenter of the study, I did not access student data until the completion of the experimental class to eliminate the possible effects of having prior knowledge about students.

As McGowan (2011) points out, "A well-designed experiment is the best method for establishing efficacy of any intervention…" (p. 1), and also states that "…if a treatment has not been extensively studied, questions exploring basic efficacy are the necessary starting point" (p. 2). Cook and Sinha (2006) also pointed out the importance of randomized experiments in writing that experiments are, "…the best available scientific tool for discovering which educational practices work and for comparing the relative benefits of different practices or programs" (p. 555). Since improved student learning is the main goal of any teaching model, and scores on assessments are the main indication of student learning, this study comparing scores from students in a traditionally taught class with students taught in a flipped classroom provided evidence of the effects of the flipped classroom on student learning.

Both the control group (class taught with a lecture-based model) and the experimental group (class taught with the flipped classroom model) were taught under similar environmental conditions, a requirement for a well-designed experiment. The identical environmental conditions include the same: semester (fall), professor, hour of day, classroom, course goals and objectives, sequence of course topics, attendance requirements, access to tutoring services at the institution, access to professor during office hours, textbook, online homework delivery system, problems in practice assignments, chapter assessments, and final exam. The only difference the students experienced is the model of instruction used.

The Control: The Traditional Precalculus Class

In the lecture-based class I shared content through lectures with the aid of visual presentation software and a whiteboard. Problem demonstrations were done during most class meetings. Students were assigned homework problems through an online homework delivery system called WebAssign. Each homework problem could be submitted for instant feedback, right or wrong, up to three times. Students were allowed to ask questions at the beginning of class before I started a lecture, and I would typically extend homework assignment due dates if students had not used up all the available submissions. Eight quizzes and four open-ended, chapter assessments were used to determine the level of student learning throughout the semester. A cumulative, multiple-choice final exam was administered at the conclusion of the course. Students were allowed to use a graphing calculator, but using the calculator was not required. Direct instruction on how to use the calculator was not part of the course. A total of 22 students completed the fall 2012 class.

The Experimental or "Flipped" Class

The experimental class was taught using a flipped classroom model based on the suggestions from Brame (2013). A total of 22 students completed the fall 2013 experimental class. Each student in the experimental group was issued an iPad since most of the components of the flipped classroom model required students to have internet access inside and outside of class. Wireless internet was accessible across the campus including student housing most of the time, and the few problems with internet access encountered during the experimental class are discussed in the results and discussion chapter. Students were given a list of course objectives identical to those from the fall 2012 class. During most classes the students were assigned a section to read and required to produce a set of notes using an adapted Cornell Note-taking system (Donohoo, 2010). Students were motivated to complete the notes because a grade was assigned. Although grading took a great deal of time, it was an important component of the flipped model. It helped me assess students' prior knowledge and provided students the motivation to follow through with the work. This was the first time I have collected and assessed student notes because it was an independent activity that warranted individual feedback.

Students were provided instructions to access video resources (Textbook, Kahn Academy, MathisPower4u.com) if they needed help while writing notes for each section. As a mechanism to assess their own learning, students were required to access an online quiz through the online homework delivery system, WebAssign. The quiz could be taken as many times as the student wished. Students received instant feedback on whether their answers were correct. These outside-of-class quiz assignments were designed to foster self-regulation and to gain exposure to course content outside of class. An effort grade was assigned for each quiz to encourage compliance with the task. Students were asked to write any questions they had in the margin of their notes to bring to the next class for discussion.

In-class time was devoted to answering students' questions about content to which they were exposed through the textbook and videos. In-class assignments and activities were designed to focus students on the higher-level cognitive process of problem solving. Examples of in-class activities included: application problems which students worked on in small groups, presentations of problems to the class, and think-pair-share activities (activities where I posed a question for students to think about after which they took turns sharing their answers with their partners). The majority of in-class time was used for students to work on problems that were traditional homework problems for the lecture-based class. The students were allowed to work with others on the problems, but each person had slight variations in the numbers used in the problems to cut down on students simply copying one anothers' answers. These in-class activities gave me a chance to work with students individually or in small groups to clarify concepts, answer questions, and give more in-depth feedback. On occasion, if I noticed the majority of students having similar questions, or if I knew students were at a place in the objectives that are prone to misunderstanding, I took a few minutes to address or instruct the whole class.

Instruments

Improved student learning is the main goal of any teaching model, and scores on assessments are the main indication of student learning, therefore, this study compares scores from students in a traditionally taught class with students taught in a flipped classroom to provide evidence of the effects of the flipped classroom on student learning. Four instructor-created, open-ended tests were used to assess student learning of the objectives from each of the four main units of study. The tests were created by choosing representative questions derived from the learning objectives established for the course. For example, a learning objective for the course was to find the equations of and sketch graphs of circles, and the representative question on the chapter test was, "State the center and radius of the circle with equation $(x-2)^2+(y+1)^2=9$ and sketch a graph of the circle." "Condense the expression, $\log_2 5+\log_2 x$, into the logarithm of a single quantity" is a test question that assesses the learning objective, use properties of logarithms to expand or condense logarithmic expressions. The tests were designed to directly assess the learning objectives created for the Precalculus course and are valid measures of student learning.

Since the chapter tests were composed of open-ended type questions, the tests were scored using a rubric that allowed for partial credit for most of the questions. A publisher-created, multiple-choice exam that included questions from all four units of study was used as a summative assessment. The control group and the "flipped" group were administered identical chapter tests and final exams. Scores on the tests and exam were the measures used to indicate student learning.

As Thorndike (1997) pointed out, "Content validity and how to evaluate it is fairly straightforward with achievement tests" (p. 141). Furthermore, Kubiszyn and Borich (2003) have stated that, "When evaluating the appropriateness of an achievement test for a particular use the strength of the evidence for a test's content validity is the single most important technical criterion an achievement test must fulfill" (p. 26). In each of the chapter tests and the final exam used in the Precalculus classes, the test items are directly related to the stated learning outcomes for the course. Jaster (2013b) devoted a considerable amount to his discussion on validity to the idea of face validity. However, as Linn and Grundland (2000) had earlier admonished, "…validity based on content considerations should not be confused with *face* validity, which refers only to the appearance of the assessment [emphasis in the original]" (p. 9).

With respect to *reliability*, Popham (2006), in agreement with most measurement experts, has stated that while, "reliability is a necessary, but insufficient, condition for [validity]…in order for a test [to be valid] it must be reliable” (p. 100). Since the chapter tests and final exam scores are valid for the assessment of student learning objectives for the course they are also reliable.

A voluntary survey (see Appendix A) asking students specific questions about what they liked and did not like about the flipped model, and what components of the flipped model helped them learn the most was administered at the end of the experimental class. The survey consisted of six selected response items, three items asking students to rank preferences, and three open-ended items. Students were handed a debriefing statement and survey after turning in their final exam that informed them that they had been in a class taught with a new method and requested that they anonymously share their feelings about the experiences they had with the new method. Field notes were written after each flipped classroom session and after student interactions during office visits. Email and other written correspondence from students were saved throughout the semester.

Finally, there was a scheduled debriefing session conducted by an independent flipped classroom model expert who collected student perceptions of their experiences with the flipped classroom model. Due to students taking longer on the final exam than expected, the expert had ten minutes of debriefing time which was not adequate for all students to share.

Data Collection and Analysis

Common statistical procedures (i.e., *t* tests) were used to determine whether the students in the two groups were comparable based on demographic data and SAT-M scores obtained from students’ college admissions data and to determine whether the flipped classroom model had an effect on students' chapter tests and final exam scores. Survey data from selected response and ranked response items were organized into a table (Appendix B) and the open-ended question responses were aggregated and like responses were grouped together to identify commonalities. Field notes and written correspondence were read at the conclusion of the course to identify peculiarities in thoughts and actions spurred by the flipped classroom experience.

Results and Discussion

Data collected for this study provided answers for the questions, “Did the flipped classroom model affect student scores?” and “How did students perceive the flipped classroom as an instructional model?” The results of this study are presented in four main sections. The Analyses of the Groups section provides demographic data to describe the control and experimental groups and the simple *t*-test results show that the two groups are comparable based on SAT-M scores. The Comparisons of Students’ Scores section provides the *t*-test results comparing chapter tests and final exam mean scores between the two groups and provides an answer to the main research question, whether the flipped classroom model of instruction has an effect on student tests and exam scores. The Survey Results section summarizes the students’ responses to the survey given to the students taught using the flipped classroom model and provides answers to the secondary research question, “How did students perceive the flipped classroom model?” Finally, the Independent Expert’s Comments reveal some interesting insights into this particular implementation of the flipped classroom.

Analyses of the Groups

Table 1 provides detail on the demographics of the precalculus students who participated in the study.

Table 1
Demographics of the Two Classes

	Fall 2012 Class (Control Group)			Fall 2013 Class (Experimental Group)		
Class	Male	Female	Total	Male	Female	Total
Freshmen	8	6	14	7	7	14
Sophomore	1	4	5	2	4	6
Junior	0	1	1	0	0	0
Senior	0	1	1	0	1	1
Total	9	12	21	9	12	21

Data reported in Table 1 describe students who completed the entire course. Three students withdrew from each class which is typical for the precalculus class based on seven years of data. Demographically, the distribution of males and females and freshmen, sophomores, juniors and seniors were similar between the two classes, and the number in each group was identical.

Since there is strong evidence that SAT-M scores are valid for predicting future success in first-year college math courses (Mattern, Patterson, & Kobrin, 2012), a comparison of the mean SAT-M scores, accessed through student application data, was made between the two classes. A Shapiro-Wilk's test (p>.05) (Razaili & Wah, 2011;Shapiro & Wilk, 1965) and a visual inspection of their histograms, normal Q-Q plots and box plots showed that the SAT-M scores were approximately normally distributed for both classes, with a skewness of -.044 (SE = .501) and a kurtosis of -1.005 (SE = .972) for the control group and a skewness of .191 (SE = .512) and a kurtosis of .398 (SE = .992) for the experimental group (Cramer, 1998; Cramer & Howitt, 2004, Doane & Seward, 2011). An independent-samples *t*-test provided evidence that the two groups were, in fact, comparable.

The difference in the mean SAT-M scores for the control class (*M*=537.1, SD=96.2) and the experimental class (*M*=510.0, SD=53.0) was not significant; *t*(31)=1.13, *p*=0.27.

Comparisons of Students' Scores

Since there appeared to be no reason to assume that the control class and experimental class were different in any relevant way, a *t*-test was used to test the difference in the mean final exam scores for students in the control class taught using a traditional model and for students in the experimental class taught using the flipped classroom model. There was not a significant difference in final exam scores for the control class (*M*=25.9, SD=9.3) and the experimental class (*M*=25.7, SD=5.4); *t*(40)=0.06, *p*=0.95. Apparently, the flipped condition had no discernable effect on final exam scores. Both groups performed equally as well. Similar results were found for each of the chapter tests summarized in Table 2.

Table 2
t-test Results for Comparison of Means on Chapter Tests and Final Exam

Test	t	df	p
Test 1	-0.16	40	0.87
Test 2	0.48	40	0.63
Test 3	0.14	40	0.89
Test 4	-0.73	40	0.47
Final Exam	0.06	40	0.95

An independent-samples *t*-test was also conducted on the mean number of absences students had in the control class and the experimental class. There was no significant difference in the mean number of student absences for the control class (*M*=4.2, SD=2.75) and the experimental class (M=4.4, SD=3.37); $t(40)=-0.23$, $p=0.82$. These results suggest that the flipped classroom model had no effect on the number of absences students accumulated.

Although the goal of implementing new instructional models is to increase student learning, the results from this study are not disheartening. The fact that students in the experimental group experienced a dramatic change in the way they have typically been taught mathematics and achieved scores similar to their peers in a traditionally taught class is encouraging. The similar scores convinced me that student scores did not suffer from the flipped classroom model. Students can succeed under this new model.

The students in the experimental group also experienced some negative issues with technology during the semester. Two major issues occurred that created frustration for students. About three weeks into the semester the online system used for the class encountered problems that persisted for approximately three weeks. The system was not completely down, but was intermittently down, and extremely slow. The problems mainly affected students at night when they tried to access the system to complete practice quizzes and use the embedded features of the online system. The system eventually returned to an acceptable usability state, but not without causing negative feelings toward the system. A second issue occurred with intermittent wireless internet access that affected most students who lived in the dormitories. The problem lasted about three weeks and caused more frustration. The issues overlapped for a while, so in total there were about four and a half weeks that students were frustrated with the technology they relied on for the class. In spite of these technology issues the students still performed as well as the control class on the common assessments. The survey results in the next section provide information about how students perceived and persisted in the flipped classroom atmosphere and elaborate upon the frustrations the students had with the technology.

Survey Results

All 21 students from the class taught with the flipped classroom model completed an anonymous survey (Appendix A) immediately following the final exam. Four closed-ended questions were designed to obtain the students' perceptions of the flipped classroom model. When comparing their experience in the flipped classroom to more traditionally taught classes, 52% of the students indicated that the flipped class was more challenging while 33% and 14% indicated the class was the same or less challenging respectively. When asked if they had to take another math class in the future 38% indicated that they would choose a flipped classroom model while 62% would choose a traditional model. Further analysis shows that of the 52% of the students who thought the flipped classroom model was more challenging, over 90% would choose not to take another math class using the flipped model. Those students may have simply disliked the flipped classroom approach because it was so different from what they have experienced in prior classes, or maybe their opinions were conditioned by their frustration with the technology issues they endured. The complete results of the selected response items and ranked items are tabulated in Appendix B.

Another result from the student perception questions on the survey was that 62% of the students felt uneasy about the course in the beginning. Most students come to class expecting a lecture and a homework assignment so it was understandable to have 62% of the students uneasy at the beginning of the course. This fact created a change in my role as I had to guide students into the process of the flipped classroom and convince them that they could learn without me lecturing every class period. Not all students were convinced even at the conclusion of the course as one student wrote on an open-ended question that, “I didn’t like it because the information wasn’t taught to my [*sic*]. In order for me to learn, I have to be taught. I don’t think I was ever taught in this class.” In the end, 52% of the students liked the instructional model, but only 19% felt the flipped classroom was a more effective model in helping them learn the material. The results from the perceptions component of the survey are similar to those of Strayer’s study (2012) in that the students perceived the flipped classroom model as having benefits, yet the difference from the traditional lecturing model left the students with an unsettled feeling.

Similar findings exist within and outside of introductory mathematics courses. Love et al. (2013) found that students participating in flipped classrooms performed as well as students in traditionally taught classrooms, but also point out that students enjoyed the flipped classes more. Since the impetus in STEM education is to attract and retain majors through introductory courses, these findings are desirable and informative. Davies et al. (2013) found in their study with students in an information systems spreadsheet course that students preferred the flipped classroom model over a simulation-based approach; the students found the flipped approach more motivating and offered more differentiation in instruction.

Since the flipped classroom model provided students with options in which to participate in learning activities outside of class, the remaining survey questions were included to help discern what tools and procedures were perceived by students to be most helpful in the course. One of the main components I used in the flipped classroom model was a standing assignment that students create notes using an adapted Cornell Note-taking system

(Donohoo, 2010). Since students had the flexibility to either read the physical textbook, use an electronic textbook, view videos that corresponded to the textbook, or search for videos on their own from two video repositories (Kahn Academy or MathisPower4u), I asked students to rank the resources they used to create the notes they submitted. Surprisingly the physical textbook had the highest mean rank for being the most used followed by the videos corresponding to the text, the electronic textbook, and the video repositories being ranked as the least used.

When asked to rank the four main activities in the course that were most helpful in learning the course objectives, students ranked the Cornell notes (Donohoo, 2010) second to last as the most helpful, yet 86% indicated that they used the notes as a reference when working on problems in class, 52% used the notes to study for chapter tests, and 76% used the notes to study for the final exam. It appears the students did not like having to do the notes outside of class, but most used the notes as a resource for other tasks in the course.

Students ranked the WebAssign graded assignments delivered through an online system during class as the most helpful activity in learning course objectives followed by the in-class activities that typically involved working in pairs or small groups on specific application problems. Some of the students' comments on the open-ended questions of the survey explained why students liked the WebAssign graded assignments. One student wrote, "I liked the graded homework assignments, I think they really helped me understand the material better. So web assign [*sic*] in general was a plus in this class." Another student wrote, "I liked that our homeworks were on web assign [*sic*] and that we got an automatic grade and help for homework." These students called the assignments homework, but the assignments were actually done in class. It was confusing to me and the students when we used the term homework, but the concept is so engrained it will take time for the language of education to catch up with the practices if flipped classroom models do become more prevalent.

Evidently, the flipped classroom model did have an effect on students even if the effect was not on student scores. Some effects were positive as expressed by the student who wrote, “I liked the web assign [*sic*] homework and videos, it [*sic*] was especially helpful. I liked the fact that we had to take notes, that way it forced me to read the book. I also liked the in group assignments. I like these things because it made me come out of my comfort zone with only learning the way I knew how to learn.” Some effects were negative such as the student who wrote, “Thanks to these ways of learning, I learned absolutely nothing.” As a professor, this type of comment hurts, but it is a reminder that not all students are going to transition to new instructional models easily.

Independent Expert’s Comments

The director of the Center of Excellence in Teaching and Learning was asked to do a debriefing session with the students in the flipped classroom immediately following the administration of the final exam and survey. Due to the length of time it took students to finish the final exam and complete the survey, the expert had only 10 minutes to engage and elicit students’ responses to the flipped model. J. S. Land (personal communication, December 10, 2013) related that the majority of the session focused on technology issues that students faced during the semester, but she was able to make the following statement:

> Comments about doing “so much work” are very common, especially when students are accustomed to traditional, less “active” teaching/learning methods. Also common

are claims the professor should have “told them what they needed to learn” aka “traditional lecture method” - which we know doesn’t yield the best results.

Summary of the Results

The comparisons of students’ mean scores on chapter tests and the final exam show that there is no significant difference between scores of those students taught using a traditional lecture mode of instruction and those taught with a flipped classroom approach. Student perceptions of the flipped classroom were mixed; some enjoyed and found benefit in the flipped classroom while others indicated and expressed that the flipped classroom was not favored and was not an effective mode of instruction.

Conclusions

Instructor Reflections

While teaching the experimental class I periodically wrote in a journal about the experiences I had in the flipped class. I kept written and emailed correspondence from the students. Through an analysis of the journal and correspondence I discovered three main effects the flipped classroom had on me: my work habits changed, I got to know my students better, and I enjoyed the classroom more.

Preparing for a flipped class for the first time was daunting. Since I did not prepare lectures, my work focused mainly on preparing class activities and assessing the notes students did outside of class. In the beginning of the course I had to assure apprehensive students that they could be successful in a course where I did not lecture. I received one handwritten note and two emails from students who were not convinced they could do the work on their own and I had to reassure them that they were not doing the work in total isolation, just differently from their typical math classes. Since my students were issued iPads at the beginning of the semester, they all had access to an application called Evernote that I required students to use to upload pictures of their handwritten notes for each designated section of material. Students gave me viewing access to their notes. I spent approximately three hours a week in the beginning making sure students were producing adequate notes, giving detailed feedback, and assigning grades. I had to explain to my colleagues one day a message I had on my office door; it said, “Sir, my Evernote won’t cloud 1.4 notes. I’m working on it.”

Since in-class activities are important elements to the flipped classroom model, I created 11 graded activities that were to be completed in class. The students enjoyed these activities because they worked in groups and they were motivated by having to present problems in front of the class for some of the activities. As an example, one activity instructed students to create a box by cutting out a square from each corner of a piece of paper and fold it in a prescribed way. The students worked in pairs, and each pair chose a different size corner to remove from the paper. They created the box, measured its length, width, and height, and calculated its volume. As a class we aggregated the various volumes and identified the size of the removed corner that produced the box with the largest volume. The students then wrote a function that would represent the volume based on the size of the removed corner, and then the students found the size of the cut corner that maximized the volume of the box. This was an activity that encompassed several of the topics on which the students had taken notes. The students were attentive throughout the activity and several made comments that they wished they did more of these types of activities in math classes.

With lecturing time diminished to practically nothing, I had more time in class actually talking *with* students instead of *at* students. While students were working on graded assignments or activities in class I would circulate around the room and watch students work. I addressed their misunderstanding of concepts immediately, and they were able to continue working. Being careful not to let one student or group monopolize my time, I kept moving. It was liberating to have the time to get to know the students better. I learned their names much quicker than I typically do, and identified students that had problems with content much quicker. The questions students had were much more specific, and the discussions we had were on a deeper level than I am used to in these introductory math classes. Students were coming to class earlier, and most of the class periods I entered the class with all the students working on assignments before I said one word. In no other classes has that ever happened.

Finally, the most beneficial effect the flipped classroom model had on me personally was that it allowed me to enjoy the classroom. Typically it is difficult for me to overlook some of the weary faces of students sitting before me as I lecture. Because I used the flipped classroom model, I didn’t have to suffer that experience class after class. Not all students were cheerful all the time in the flipped class, but there was enough change going on each class period that eventually every student made some effort to engage in the activities. There was resistance, but overall the class felt good to me. I enjoyed teaching, or a better term would be facilitating, in the flipped classroom.

Limitations of the Current Study

After experiencing the flipped classroom and closely interacting with the students involved, I continue to be persuaded that the flipped model is an instruction design that has the potential to increase student learning. There are three factors within my specific implementation that I feel could have curbed the gains I expected to see in students’ scores. The factors are presented herein no particular order and are accompanied by suggestions that may help others wishing to further experiment with the flipped model.

The flipped classroom design in mathematics was new for all of the students in the experimental class. It required the students to do more independent work than is typically called for in traditionally taught classes. The changes I implemented, starting with the first day of class, were so abrupt that some of the students notified me within the first three class sessions that they did not think they would be able to succeed in this type of environment. Before they even understood completely the expectations of the class, they had decided it would not work for them because it was not like their high school math classes. The change was so different from what they expected it predisposed them to have negative feelings about their abilities, which were difficult to overcome and in one case a student never fully accepted the challenge. When flipping a mathematics class, there may need to be a transition period where students have some time to get accustomed to a flipped approach. For example, the next time I flip I will probably lecture for a short amount of time in the first few classes, show the students where they could have found the same information through video resources or the textbook, and then slowly transition the students into doing the outside-of-class assignments more independently.

Another factor that may have impeded higher scores for students was the flexibility I offered with the resources students were pointed to in doing the outside-of-class note taking. In my naiveté with the flipped approach, I offered students choices of resources to use to find the information they needed to prepare for class: the textbook, videos provided with the textbook, and two alternative video repositories. I did not require students to watch videos, and the majority of them chose solely to use the textbook. This was not what I expected; I thought the students would gravitate to the video resources. In hindsight, I believe offering multiple video repositories was either confusing or overwhelming for the students. A more structured and required path for gaining the outside-of-class information may have been more beneficial to the students. It may be even more fruitful, although more time consuming, to create videos for the class. Videos could be tailored for the specific students in the class, and the unique classroom dynamics that occur from semester to semester. With the technology available today, this suggestion is not as far out of the realm of possibilities as it once was.

The final factor that disrupted my implementation of the flipped classroom was the technology glitches described earlier. The reliance on internet access and the stability of online services are important considerations when using the flipped model. Since I did not create my own videos for this experiment, I relied on online services to provide access to the video content. Students may have been jaded when they encountered problems with accessing the videos online, and gave up trying to use those resources for the remainder of the course. Students were required to use other online services as well to post their notes, and take practice quizzes. Once these services were interrupted or difficult to access the students had only the physical textbook available. These technology glitches did not last the entire semester, but having an alternate plan may have been helpful during those difficult times. If I had created my own videos, I could have made them available to students through DVDs or flash drives. Then the internet disruption may not have had as much of an effect on students' use of those resources.

The suggestions I have made could have an effect on student learning. Developing more of the classroom procedures based on the learning theories discussed in the literature review that support the flipped classroom model could potentially help students learning. With more students being exposed to the flipped classroom approach in high schools, the likelihood that different results would be found in studies like this is much higher.

Although the flipped class model used in this study did not have a significant effect on student scores, there was encouraging evidence that the model is worthy of further research. The fact that the study did reveal that students' scores from the class taught with a flipped classroom model are the same as students taught with a traditional lecture-only model is important. The flipped model definitely had a positive effect on me as a professor. It allowed me to understand my students better, and gave me the time to participate with students in learning the content of the course. It made me aware that students need more than lectures about the content. They have to experience the content for themselves. It is fun being a guide to the students, and having meaningful conversations about math.

Recommendations for Future Study

This study provides evidence for the viability of the flipped classroom model, but more research is needed. Since the flipped classroom model is so new, especially in introductory college math classes, and comes alongside a mode of instruction that has not been substantially challenged for hundreds of years, it is exciting to see that interest is growing in this advantageous model of instruction. The results of this study have sparked several questions that should be explored.

The abruptness of changing instructional methods seemed to have a substantial effect on students' perceptions. Studies need to be conducted that make a more gradual transition to the flipped classroom to see if the anxiety of the new method can be alleviated. Now that more professors and high school teachers are experimenting with the flipped classroom studies will need to include comparisons of students who have and have not been exposed to the flipped classroom models. Longitudinal studies should now be considered to see the lasting effects of the flipped classroom. Will student perceptions of the flipped classroom change as they encounter more classes that use the model? Will the effects of flipped classroom change when students become more comfortable with flipped classrooms?

Other areas of interest include the tools and technology that is continuously changing to help implement flipped classrooms. As technology changes there exists more possibilities to create classrooms that implement elements that tie to suggestions from the teaching and learning literature. Do students respond more favorably to more crude types of instructor-created videos or do they prefer more professionally-created videos? Does the length of videos effect the motivation of students to persist with viewing? Exploring these questions will help future professors and teachers know the best practices of incorporating flipped classroom elements.

With further research the flipped classroom model can become a strong contender to help change educational practices. I have to agree with a statement made by Goodwin and Miller (2013):

> What inverted classrooms may really be flipping is not just the classroom, but the entire paradigm of teaching-away from a traditional model of teachers as imparters of knowledge and toward a model of teachers as coaches who carefully observe students, identify their learning needs, and guide them to higher levels of learning. (p.79)

This new paradigm has been around for a while, but the flipped classroom model is a vehicle that has the potential to take education in a more meaningful direction.

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Appendix A

Perceptions of a New Model for Teaching Precalculus

You have participated in a precalculus class this semester that used a model of instruction that is probably much different from the instructional models you have encountered in previous math classes. I would like to know your opinions about this new model of instruction using this anonymous survey. Although this survey is not required, and participation is voluntary, I am asking you to complete the survey for research purposes, and to help improve the course for other students in the future. Your decision to participate in this survey will have no effect on your course grade. Your responses will not be read until grades have been submitted for the course. If you have any questions or concerns about this survey you can contact me at jwillis@gardner-webb.edu or Dr. George Olson, my project advisor, at olsongh@appstate.edu .

1. Compared to traditional math classes you have taken, did you find learning in this class:
   (choose one)
   - ☐ less challenging than other math classes
   - ☐ about the same as other math classes
   - ☐ more challenging than other classes

2. What resources did you use to gather information to create notes? Rank order the resources from 1 to 5 with 1 being the most used, 2 the next most used, 3 the next, and so on. Use 5 to indicate the least used.

   ______ electronic textbook (ebook)

   ______ physical textbook

   ______ videos within WebAssign

   ______ videos from Kahn Academy

   ______ videos from MathisPower4u website

3. Which of the following resources did you use to get the **best** help when you did not understand a problem? Rank the top 5 resources with 1 being the most helpful, 2 the second most helpful, 3 the third most helpful, and so on. You need only rank the top 5, and leave the others blank.

_____ electronic textbook (ebook)

_____ physical textbook

_____ professor

_____ tutor

_____ videos from MathisPower4u website

_____ videos within WebAssign

_____ videos from Kahn Academy

_____ friend outside of class

_____ classmate

4. Which of the following activities did you find most helpful in learning the objectives for the course? Rank the following activities from 1 to 4 with 1 being the most helpful, 2 being the next most helpful, and so on. Use 4 to indicate the least helpful.

_____ Producing the Cornell notes

_____ WebAssign Personal Study Plan Quizzes

_____ WebAssign graded assignments

_____ In-class activities (creating a Show Me, partner work with application problems, etc.)

5. If you had to take another math class in the future, which type of class would you choose?

☐ One that uses the model used in this precalculus class

☐ One that uses a traditional model

6. What one device did you use the **most** to complete the work for this class?

☐ iPad

☐ Laptop

☐ Personal Desktop

☐ Computer in a campus computer lab

7. After creating your notes for each section of material, did you use your notes to:

   …look up formulas or procedures while working on problems? ☐ Yes ☐ No

   …study for chapter tests? ☐ Yes ☐ No

   …study for the final exam? ☐ Yes ☐ No

8. Which one description best indicates how you felt about the instructional model used in this class?

   ☐ The model made me uneasy at first, but overall I liked it
   ☐ The model made me uneasy at first, and I never liked it
   ☐ The model interested me at first, and I liked it all the way through
   ☐ The model interested me at first, but overall I did not like it

9. How did you feel about working problems in class, and gaining first exposure to content outside of class?

   ☐ I liked the switch, and felt it was more effective than a traditional model
   ☐ I liked the switch, but felt it was no more effective than a traditional model
   ☐ I did not like the switch, and felt it was no more effective than a traditional model
   ☐ I did not like the switch, but felt it was more effective than a traditional model

10. If you liked the course, please describe what factors of the course you liked, and why.

11. If you did not like the course, please describe the factors that you did not like, and why.

12. Do you have further comments that you would like to make concerning the instructional model used in this class?

Appendix B

Table B1

Summary of Selected Response Items

Item	Responses	n	%
1. Compared to traditional math classes, did you find learning in this class:			
	Less challenging	3	14
	About the same	7	33
	More challenging	11	52
5. If you had to take another math class, which type of class would you choose?			
	One that uses the model used in this class	8	38
	One that uses a traditional model	13	62
6. What one device did you use the most to complete the work for this class?			
	iPad	3	14
	Laptop	18	86
7. After creating notes for each section of material, did you use your notes to:			
	Look up formulas or procedures while working on problems in/out of class?		
	Yes	18	86
	No	3	14
	Study for chapter tests		
	Yes	11	52
	No	10	40
	Study for the final exam		
	Yes	16	76
	No	5	24
8. Which one description best indicates how you felt about the instructional model used in this class?			
	The model made me uneasy at first, but overall I liked it.	10	48
	The model made me uneasy at first, and I never liked it.	3	14
	The model interested me at first, and I liked it all the way through.	1	5
	The model interested me at first, but overall I did not like it.	7	33
9. How did you feel about working problems in class, and gaining first exposure to content outside of class?			
	I liked the switch, and felt it was more effective than a traditional model.	4	19
	I liked the switch, but felt it was no more effective than a traditional model.	9	43
	I did not like the switch, and felt it was no more effective than a traditional model.	8	38

Note. Item numbering corresponds to survey in Appendix A.

Table B2

Summary of Ranked Response Items

Item	Response	n	Mean Rank
2. What resources did you use to gather information to create notes? Rank the resources from 1 to 5 with 1 being the most used and 5 being the least used.			
	Physical textbook	21	1.5
	Videos within WebAssign	21	2.2
	Electronic textbook	21	3.1
	Videos from Kahn Academy	21	3.9
	Videos from MathisPower4u website	21	4.3
3. Which of the following resources did you use to get the best help when you did not understand a problem? Rank your top 5 choices with 1 being the most helpful and 5 being the least helpful.			
	Videos within WebAssign	19	2.0
	Professor	16	2.6
	Physical textbook	17	2.8
	Classmate	15	2.9
	Electronic textbook	6	3.3
	Tutor	3	3.7
	Videos from Kahn Academy	7	4.0
	Friend outside of class	9	4.0
	Videos from MathisPower4u website	5	4.4
4. Which of the following activities did you find most helpful in learning the objectives for the course? Rank the activities from 1 to 4 with 1 being the most helpful and 4 being the least helpful.			
	WebAssign graded assignments	21	1.5
	In-class activities	21	2.5
	Producing the Cornell notes	21	3.0
	WebAssign Personal Study Plan Quizzes	21	3.1

Note. Item numbering corresponds to survey in Appendix A.

Vita

Jason A. Willis was born in Shelby, NC. After completing his compulsory education at East Burke High School in 1992, Jason entered Appalachian State University. He received a Bachelor of Science degree with a major in Secondary Mathematics Education in 1996. While teaching high school full time, Jason achieved a Master of Arts degree in Mathematics Education from Appalachian State University in 1999. He left high school teaching in 2001 to pursue interests in technology and healthcare. Jason returned to the high school scene as a technology facilitator and computer programming teacher in 2003. After four years in the high school and teaching as an evening, adjunct instructor for Gardner-Webb University, Jason joined Gardner-Webb as a full-time mathematics instructor in 2007. In 2011 Jason was promoted to Assistant Professor at Gardner-Webb University. In August 2014 he received the degree of Doctor of Education from Appalachian State University, and continues to teach at Gardner-Webb University. Jason resides in Shelby, NC with his wife and two children.